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LABORATORY INVESTIGATION OF CEMENT PERMEABILITY BY USING DIFFERENT CHEMICALS

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ABSTRACT

Cement integrity is the key factor for thelong-term and future prospecting of the oil well having low permeability and decreasing its transitional time. Ultimately it provides a lending sheath to the well casing for future production preventing the collapse of formation as well as serve as a barrier for fluid movement between permeable zones. Permeability development within the cement increasesthe transitional time which results in loss of integrity and filtration may reduce the efficiency of cement leading to unsympathetic economic impact. Therefore determination of cement permeability by OFITE 120-87 has been considered useful to mitigate the wellbore problems associated with poor cementing.

The objective of present study is to conduct an experimental investigation of the cement permeability by using the cement permeameter (OFITE 120-87) at ambient conditions. The permeameter being used in this study is designed to determine the permeability of cement core specimen 1” X 1”. The core specimen is placed into the core sleeve and then placed into the test cell known as “modified hassle “.The nitrogen gas is passed through the core specimen. The flow rate across the sample is recorded by a calibrated flow meter. The viscosity of flowing gas is 0.1756 cp at 25^{0}C.The variables from the study are integrated into Darcy law to calculate sample’s permeability.

Keywords: Class G cement, cement permeameter, chemical additives and distilled water

1. INTRODUCTION

The foremost function of primary cementing is to achieve zonal isolation in order to prevent the fluid migration and ensure long-term cement integrity during the lifetime of the well. Current advanced drilling and cementing technologies enable the production of oil and gas in more complex challenging conditions such as deep wells and unconventional wells either onshore or offshore. Effective primary cementing would include a good casing-cement bond, cement-formation bond and ability of cement to prevent flow through it. The properties of the cement slurry and its behavior depend on the components and additives of the cement slurry design.

The cement permeability is also a key parameter in ensuring the durability of well throughout the production lifetime. Cement must have an impermeable matrix in order to provide zonal isolation

High cement permeability may lead to secondary cementing operation requiring additional expense. In thecase of severe conditions, welldamage can occur as well. These cement properties depend on various factors such as water to cement ratio, curing time, confining pressure and temperature and additives used to strengthen the cement.

The permeability of cement to gas is normally greater than the liquid permeability. The value of cement permeability without any additives is greater than 0.1md. The cement class G and H samples with various densities are aged under high-temperature conditions. During experimental work low permeability value was observed initially. However, the cement permeability was increased to 10 mdsover time. (Nelson, 1990)

Longer transitional time for cement slurry may become a cause of gas leakage or gas migration due to certain slurry performance. Gas migration can be prevented by speeding up the slurry from theliquid phase to thesolid phase by using thehighly efficient slurry to develop early age compressive strength.

Especially in the high-pressure gas wells, it is essential to control the flow of gas through the cement. In thecase of high cement permeability, the fluids may seep into the shallow portion of the formation near to the surface which may cause anincrease in pressure of shallow portion which then resultsin blowouts, weaker zonal isolation, and loss of reserves(Nelson, 1990).

Various laboratory tests could be carried out by using different additives at different concentrations to determine the cement permeability through cement permeameter. In this study,the cement, permeameter equipment is used to investigate the permeability by using Class G oil well cement with different proportion of additives and water to cement ratio at ambient conditions. This analysis will help in thebetter selection of cement slurry with anaccurate ratio of additives and water suitable for downhole conditions.

2. Literature Review:

Ozyurtkan, Altun, Mihcakan, & Serpen(2013)studied an experimental investigation for the prevention of permeability development within and around the set cement at ambient conditions by using the natural magnesium complex with carbonate (ARI) as a cement additive. Gas permeability measurements were conducted on 7” samples of 19 different compositions cured for a period of 1, 7 and 28days. Slurry was prepared using class G cement with 2% of ARI, 0.4% of viscosity control (CFR3) and 0.7% of water loss control (HALAD-9) additives by weight of cement, respectively. ARI additive was added to cement slurry with a ratio of 3% and 5%BWOC. It was revealed from the study that permeability of cement sample were decreased with addition of 3% of ARI BWOC and completely eliminated with the addition of 5% of ARI BWOC for all long aging time periods.

Roshan & Asef(2010)investigated the effect of carboxymethylcellulose(CMC) containing other additives on oil well cement in the Iran field focus to tectonically induce horizontally in-situ stress. On the basis of six months tests, the primary impact of additive carboxymethylcellulose CMC was observed on oil well cement. Temperature, density and Pressure of all tests were measured at 125^{o}C, 5200psi and 117 Lbm/ft^3 respectively. The cement permeability was measured at 100psi and 20 ^{o}C after 24hours. It was found that permeability decreases from nearly 0.3md to less the 0.1md by addition of 0.4% of CMC. Furthermore,researchers also measured the early high compressive strength of cement at different ranges of proportions of CMC and friction reducer. It was observed

that the compressive strength increased by 37% at 0.2% CMC and 0.5% FR. It was concluded that extra CMC will remain undissolved and will have a negative impact on cement strength.

The flow of gas through cement sheath should be controlled, especially in high pressurized gas wells. If the cement is permeable enough, the fluids may percolate up to shallow portion of the formation around the well and/or to the surface. Such situations may cause an increase in the pressure of a shallow portion of the well, blowouts, weaker zonal isolations and production losses. (Nelson, 1990)

Vazquez, Blanco, & Colina(2005)evaluated the flow potential factor of three wells in Santa Barbara and San Joaquin fields located in Eastern Venezuela for optimum cement slurry design that prevents the industrial accidents and assuring the well life. The cement slurry formulation of three wells was evaluated. Results showed no gas migration for well 1, well 2 and well 3, in agreement with field observation. It was concluded that the slurry transition time must be based on the well FPF values. It is important to measure the FPF for each well for thelongterm integrity.

(Karakosta et al., 2015) presented a comprehensive laboratory assessment of the properties of two different non-foamed cement slurries such as fluid loss, thickening time and strength. He prepared two different slurries using class G cement with 43.8% and 31.3% of water BWOC according to API procedures. It was revealed from the study that NMR and ultrasonic measurement provide a comprehensive methodology for predicting the hydration properties of cement slurries with various additives at borehole conditions. Furthermore, it was found that addition of micronized silica increases the hydration rate significantly due to the effect of addition.

3. EXPERIMENTAL STUDY

3.1 Preparation of cement slurry and specimen

The cement slurry prepared according to the API recommended practice 10B for oil well cement. The procedure described below is recommended for laboratory preparation of slurries that require no special mixing conditions.

Step-IThe amount of class G cement and additives (barite, bentonite and caustic soda) with different proportions was weighted by electronic balance.

Step-II Class G cement and additives with different ratios was thoroughly and uniformly mixed prior to adding distilled water.

Step-III The cement and additives were added to the distilled water in a slurry blender and mixed continuously at 12000 rpm for 50 seconds. The temperature of dry cement and mix water was maintained at 20 ^{o}C -23^{o}C.

Step-IV The density of cement slurry was measured by mud balance and reported to be 15ppg (Pounds Per Gallon).

Step-V Slurry was prepared and then poured into a clean brass mold of 1” X 1” inch in length and diameter which had been placed on a flat plate and sealed. Then theslurry was puddled many times with stirring rod and leveled with a spatula. A top plate was carefully placed on the mold, so as not to trap air bubbles in the sample. See below figure.

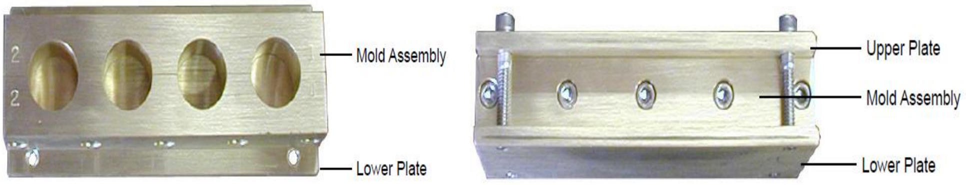

Fig 1: Four Gang Brass mold of 1” X 1” in length and diameter.

Step-VI Sufficient settling time was provided to the cement specimen to harden the cement.

Step-VIICement specimens were then cured for 24 hours and 48 hours after removing them from the mold.

The cement slurries were prepared at 12ppg and 15ppg by using different proportions of bentonite, barite and water to cement ratio. The composition of cement sample with different percentage of bentonite and barite are given below.

Slurry-I contained 1% and 1.5%of barite BWOC with 15ppg density

Slurry-II contained 1% and 1.5% of bentonite BWOC with 12ppg density

Above samples were then cured for 24 and 48 hours in a water bath maintained at 27^{0}C. The permeability was then measured through cement permeameter.

Fig 2: Cement specimens with different proportions of chemicals prepared in Laboratory

3.2 Experimental procedure

The cement permeameter OFITE-120 is designed to measure the permeability of cement specimen of 1'' x 1'' in diameter and length as shown in the figure 3. A cement specimen is placed into core sleeve, which is then inserted into the "Modified Hassler" style test cell. The nitrogen at constant flow rate is passed through the cement and differential pressure across the cement is measured. The flow rate is measured with calibrated flow meters. The viscosity of nitrogen is 0.01756 cp. These variables are integrated into Darcy's law to calculate cement sample permeability.

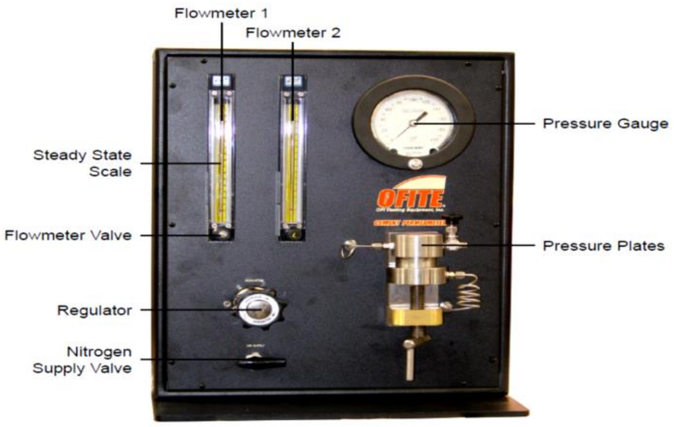

Fig 3: Cement Permeameter (OFITE Testing Equipment Inc.)

The Modified Hassler test cell accommodates the cement sample of 1'' length and 1''diameter. All Hassler components are fabricated from stainless steel. The flowmaters are used for low and high range flow-metering. Flow meter 2 is much more sensitive than Flow meter 1. If Flow meter1 does not register any appreciable flow rate at 180 PSI (1,249 kPa) then Flow meter 2 is used to take the readings. The nitrogen gas is supplied through the nitrogen supply valve by turning pressure regulator clockwise. Inlet pressure of nitrogen can be measured by the pressure gauge.

Permeability is calculated via Darcy's Law, which is stated mathematically

$$K = \frac{2000 P_o Q \mu L}{A(P_1^2 - P_o^2)}$$

Where *K* = Permeability, md
Po = Outlet Pressure, psig
Pi = Inlet pressure, psi
Q = Flow rate, cc/sec
µ = Viscosity, cp
L = Specimen Length, cm
A = Cross Sectional Area, cm^2

The cement specimen was placed into a rubber holder and which was then placed in to a rubber holder in the sleeve. Then the bottom plate was screwed upwards and tightened to ensure a good seal between the specimen and rubber holder as shown in the figure. The nitrogen gas was then supplied to the cement through the nitrogen supply valve. The valve of flowmeter 1 opened until the steady state scale reading on the flow meters registers 10. We record the inlet pressure (P1) from the pressure gauge. This procedure was repeated by opening the regulator and recording five

readings of inlet pressure at different intervals of each sample. The obtained values of flow meter and pressure were the substituted in the Darcy's equation to determine the permeability of each specimen.

Fig 4: Specimen holder, sleeve and test cell of Cement Permeameter OFITE-120

3.3 Results and Discussion

The gas permeability test results of the cement specimen with different proportions of additives and water to cement ratio areevaluatedand presented below.

The additive barite was added to the cement slurry with a ratio of 1%, and 1.5% BWOC. The gas permeability tests were performed after thecuring period of 24 hours and 48 hours. The results obtained from these experiments are summarized in Table 1.

Amount of barite % BWOC	Permeability , md	
	Curing periods, hours	
	24	48
1	0.60	0.25
1.5	0.48	0.11

Table 1: Permeability values cement specimen with various % of Barite.

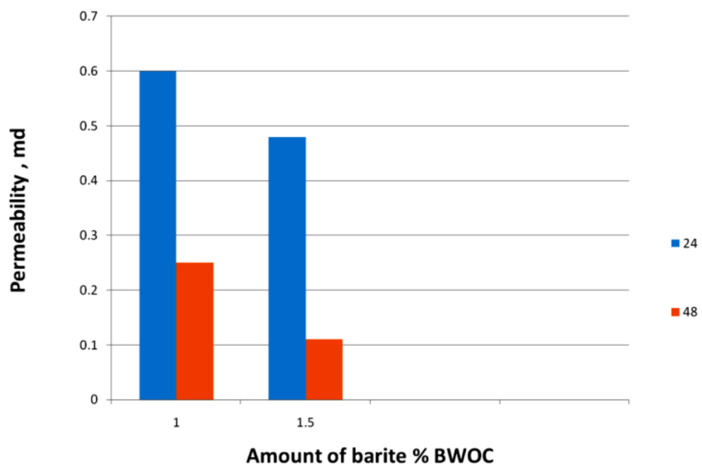

Fig 4: Graph - Permeability values cement specimen with various % of Barite.

The additive bentonite was added to the cement slurry with a ratio of 1% and 1.5% BWOC. The gas permeability tests were performed after the curing period of 24 hours and 48 hours. The results obtained from these experiments are summarized in Table 2.

Amount of Bentonite % BWOC	Permeability , md	
	Curing periods, hours	
	24	48
1	0.85	0.40
1.5	1.2	0.6

Table 2: Permeability values cement specimen with various % of Bentonite

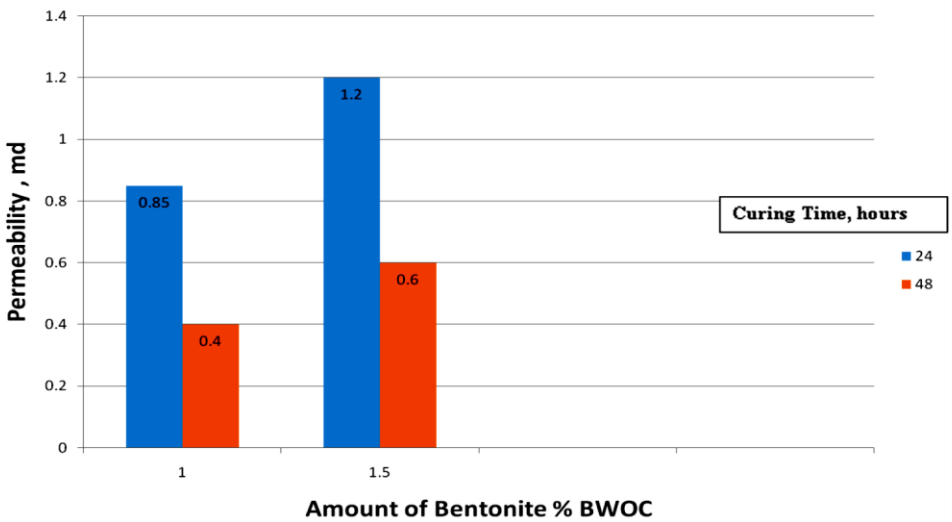

Fig5: Permeability values cement specimen with various % of Bentonite

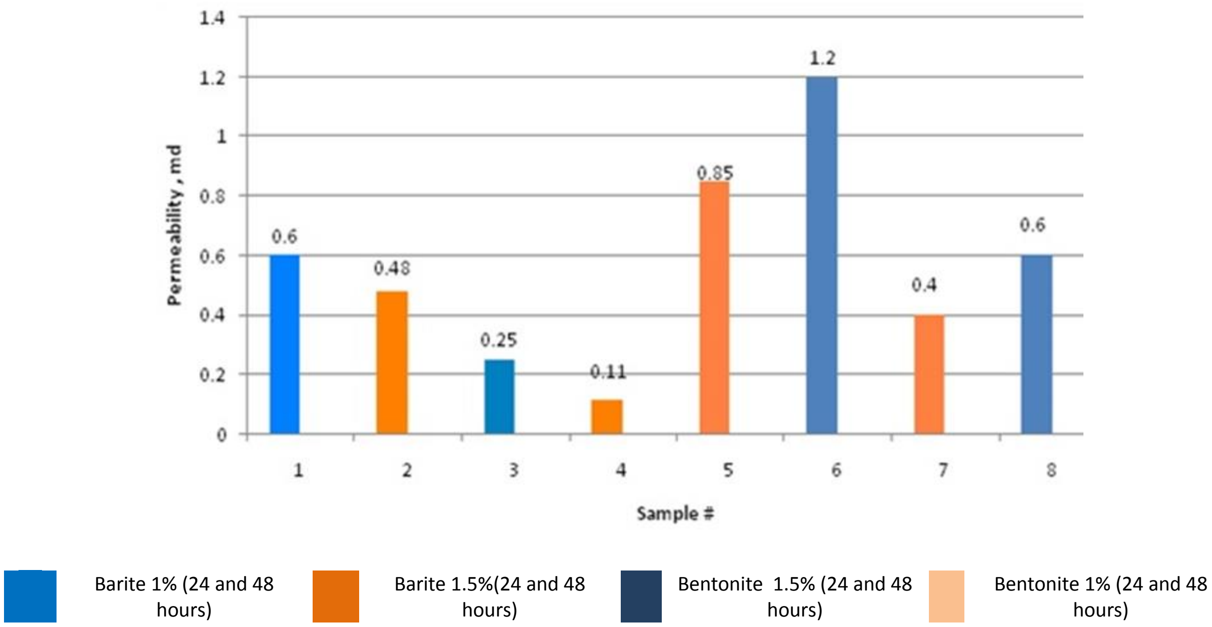

Fig 6: Permeability values of various cement specimens with different % of Barite and Bentonite.

CONCLUSION

The light cement slurry with 12ppg was prepared by using bentonite. It is noted that permeability can be decreased with increasing curing time to 48 hrs due to the increase in compressive strength.

The density of 15ppg slurry was prepared by using barite concentrations. It is noted that permeability was reduced by increasing curing time and it became more stable reducing filtration.

NOMENCLATURE

BWOC= by weight on cement
md= Millidarcy
cp= Centipoise
cm= Centimeter
cc/sec =Cubic centimeter per scond
atm = Atmospheric pressure
ppg =Pounds per gallon

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